larger scale the particular kind of experiment which I have here narrated as a very small one. I make the remark here, because I know the value in any such experiment of that kind of co-operation and encouragement to which I have had occasion gratefully to allude in mentioning the names of Messrs. Sherwin and M'Lelland, and I am not so absurdly proud or self-confident as to fail to bespeak it. I believe that a man can scarcely adopt a more useful or delightful pursuit to which to devote his time, his attention, and his means, than one which enables him, even in a small way, to add to or extend the productions of the earth, to endeavour humbly to supplement Nature in the supply of the multifarious blessings which she sheds around us, and to multiply legitimate enjoyments amongst the people.

ART. VIII.—*On the Supply of Water to the Town of Geelong. By* JOHN MILLAR, *Esq., C.E., F.S.A., &c. Engineer-in-Chief to the Geelong Water Commission.*

[Read before the Institute 6th May, 1857.]

HAVING had the honour of being appointed Engineer to the Water Commission of Geelong, and seeing that the supply of life's great essential, pure and unadulterated water, to the inhabitants of any portion of this colony, is so intimately interwoven with the well-being of all, being a part and parcel of our vital interests, so essentially necessary to the enjoyment of perfect health that it must be a subject of universal importance, I therefore propose placing before the Institute a general summary of what has been done under my commission towards the accomplishment of that object, and the attendant results of my labours.

I am perfectly sensible of the risk I incur in making statements on this subject, even when based on a sound theory, coupled with long practice, and strengthened by such statistical information as I may have been enabled to collect; aided as I may be by all this, yet statements of a startling nature may appear incredible to those whose attention has never been directed to such matters; if any such should doubt the accuracy of my conclusions, I can only say that they rest on facts which I conceive to be incontrovertible.

I beg leave to rapidly review the past, and in the general order in which my duties as Engineer to the Commission have been undertaken.

First, I shall briefly advert to three modes of supply which have heretofore been proposed by others, prior to my connexion with the Commission, as shewn by the accompanying:

TABLE No. I.

Proposed Sources of Supply for Geelong, shewing Altitudes, &c.

Date.	*Proposers.*	*Nature of Scheme.*	*Where From.*	*Alti. above high water, Corio Bay.*	*Population.*	*Consumption per head per diem.*	*Proof head of water pipes equal to a column of water 800 ft. altitude.*
						galls.	
1852	Mr. Henry ...	*Pumping* & gravitation combined.	Buckley's Falls, River Barwon.	182	20,000	10	
1853	Mr. Taylor ...	*Pumping.*	Ditto.	361	30,000	10	
1856	Mr. Darbyshire	Pumping & gravitation combined.	Ditto.	224	30,000	10	
1857	Mr. Millar, Engineer-in-chief to Water Commission.	GRAVITATION.	Wormbete.	405	50,000	50	Safe Head, 400 ft. To which pressure pipe castings may be ordered for town, and to which they will constantly be exposed.

First, in 1852, Mr. Henry's—A pumping and very partial gravitation scheme combined: a crude and undigested plan, upon a very low scale.

Second, in 1853, Mr. Taylor's—A pumping scheme.

Third, Mr. Darbyshire's—A modification embracing both the foregoing plans, being a combined pumping and gravitation scheme, from the River Barwon, at Buckley's Falls, (at an altitude of fifty-four feet above high water mark in Corio Bay) from whence the water was to be raised by pumping to an additional altitude of one hundred and seventy feet, thus supplying (Geelong proper) a population of 30,000, at a limited consumption of but ten gallons per head per diem.

On the engineering merits of this scheme it will not be

necessary for me to make any observations, as a fatal objection occurs at the very outset of its consideration, namely, in the quality of the water it is proposed to afford.—(*Vide* Dr. Macadam's analyses and Report.)

Subsequently, and very lately, another proposition has been mooted, namely, an extension of the Yan Yean to Geelong. It requires but the enumeration of a very few counter-reasons to set aside so futile a scheme.

To those not quite conversant with the Yan Yean scheme, I may briefly say that it is the name of the reservoir which is intended to supply Melbourne with water. It is an extensive natural basin, comparatively shallow, covering about 1300 acres, into which the waters of the River Plenty are directed, and is situated five hundred and ninety-five feet above the level of Hobson's Bay.

The water, if brought in an unbroken line to the city, (assuming the pipes to stand the pressure, which they will not do unless by the intervention of self-acting "pressure reducing valves,) would command the highest houses. It is, however, imperative on that Commission to filter their water from its vegetable and other impurities; and it is their intention to construct such filters adjacentto the line of mains at Darebin Creek, about midway, say three hundred feet, above datum; therefore the pressure, in relation to the height of the highest houses in Melbourne or elsewhere, must be reckoned only from the altitude of the service reservoir supplied from the filter-beds.

The length of pipe main conveying the water to Melbourne is about twenty miles; and the idea is to continue a sub-main (branching to Williamstown) along the Geelong and Melbourne Company's Railway to Geelong, the distance being an additional fifty miles, to be fed by the re-erection of the old Collingwood cast-iron tank, at North Melbourne, from whence Williamstown and Geelong would be *permitted* to get a *night supply*, thereby re-introducing and perpetuating (on the supposition of there being water to spare) the exploded intermitting system.

Besides, in alluding to it at all, which of necessity I am called on to do, as the only work of the kind as yet approaching completion in the colony, there are certain geographical and physical considerations which I should notice, were it not that by so doing, I would run this paper to a greater length than I had contemplated. Seeing, however, that attempts have been made to foist this water on the district to which I have

the honour to be engineer, and having proved the great difference of purity between our own and the water in the Yan Yean reservoir, I therefore object on principle to its introduction to Geelong.

One, among other errors, which might have been obviated by the appliances of engineering forethought and skill, namely, the shallow embankment, causing the back water for a considerable acreage within its perimeter to be so shallow in its depth as must inevitably cause increased loss from extra evaporation, absorption, and the moisture entering vegetable life; consequently rendering the water apt to vegetate and become highly impure.

What a splendid opportunity was here lost, and which presents itself to a comprehensive mind, in the possibility of having the finest artificial inland lake in the world, impounding water enough, and to spare; the annual value of which, as a motive power alone, or for irrigation purposes, would have been equivalent to the interest of the entire expenditure, large as it has been.

In addition to the first outlay in such a proposition for supplying Geelong, there would be an annual charge by the Melbourne Commission for the water itself; and I may mention that their scale being, to large consumers, six shillings per thousand gallons, it follows that at this rate, on my estimated consumption of fifty gallons per head per diem, it would amount to an annual tax of £5 9*s.* 6*d.* on man, woman, and child; or on the population of 50,000 to £273,750 per annum—a sum, less than two years' expenditure of which, on our own account, would be more than sufficient to give us the same quantities per head on an increased population for many generations to come.

On the supposition even that the Melbourne Commission modified this rate for Geelong, it would still remain a fallacy.

In reference to such a proposition, I would observe that the Yan Yean Water-works are as yet untried; it is true that the floods of a more than ordinary wet winter have all but filled the reservoir, and disappointed the prognostications of some, who had fears on the subject. It is my own opinion, however, that with some modification, it will prove ample as regards *quantity* for the purposes for which it was *originally designed*, and a little more. I would therefore seriously advise the proposers of so preposterous an extension not to step out of their own proper sphere, to remember the adage that "charity begins at home," in good truth not to be spendthrift-

like, reckless of consequences, seeing that the numerous suburban towns and villages springing up around Melbourne, many of which will ultimately be amalgamated with the city itself, must, as matter of necessity, and that at no distate date, be supplied, whilst their out-lying neighbours, such as Geelong, might be famishing for that which Yan Yean had not the means of bestowing. That my views will coincide with the majority of observers I doubt not, when I enumerate a few of the places dependent on Melbourne for their supply, such as—

Preston	Parkside,	St. Kilda,
Northcote,	Flemington,	Emerald Hill,
Pentridge,	Moonee Ponds,	Prahran,
Brunswick,	Essendon,	South Yarra,
Collingwood,	Keilor,	Windsor,
North Melbourne,	Williamstown,	Upper Hawthorne,
South Melbourne,	Footscray,	Lower Hawthorne,
East Melbourne,	Brighton,	Kew,
Richmond,	Sandridge,	Heidelberg,

and a host of others. A goodly list of off-shoots; and from the enumeration, who can say what would remain for Geelong, after all had been supplied? particularly if a succession of dry seasons set in, which has happened before, and unquestionably may occur again.

Seeing that I quite disagree with the mere modicum of twenty-five gallons per head per diem allowed to Melbourne, I append a table showing the quantities allowed by the London and other Companies, in climates scarcely requiring one-half as much as ours :—

TABLE No. II.

SUPPLY ALLOWED BY VARIOUS COMPANIES IN EUROPE AND AMERICA.

London.	Grand Junction	..	72½	gallons
	Southwark	..	34	„
	New River	..	48	„
	West Middlesex	..	36½	„
	Chelsea	..	33½	„
	East London	..	24	„
	Croydon	...	100	„
	Nottingham	...	40	„
	Whitehaven	...	50	„
	Glasgow	..	50	„
	Ancient Rome	...	310	„
	New York	...	300	„

average of forty gallons per head per diem.

To the above table I have appended the supply to Ancient Rome, after which all our modern ideas sink into insignificance, proving the luxuriousness of that age, which is said on the authority of Sextus Julius Frontinus to have been 310 gallons per head per diem, and conveyed a distance of upwards of fifty miles in aqueducts, supported on seven thousand arches, of great magnitude, many of which are still in existence—examples of the ancient magnificence and finely cultivated taste of the Roman people.

It is only by a patient investigation of the traces of ancient civilization as they survive in such public works, that we are enabled to form correct ideas of its real condition. The care taken by the Romans to ensure to all classes of society the full and comparatively free enjoyment of the first necessaries of life, indicates that if theirs was an iron rule its despotism was greatly counteracted by its intelligence, as witness the careful foresight in providing an abundant supply, evidently irrespective of outlay, for every use conducive to cleanliness, whereby every Roman citizen enjoyed the luxury of a bath, free of cost.

In modern times, particularly in the mother country, this matter—water supply—is still a vexed question, and has either been thrown into the hands of the local authorities or left to the enterprise of private companies, which has necessarily superinduced a mode of treating such works in a way but little conducive to the display of grandeur or magnificence; the great end sought after (and generally obtained) being a good dividend at the expense of the people. The consequences of the rigorous application of which principle have been such that the mother country scarcely possesses one work connected with the supply of water, to be quoted, for its boldness of conception, grandeur of design, or as a parallel to the Roman example alluded to.

Let us hope, and I believe, we have struck on a happy medium in Victoria—an amalgamation of the ancient system of management, (without its despotism)—with modern science in designing and conducting these great works, so conducive to the general prosperity of the colony. The management being placed in the hands of the representatives of the people, each commission being responsible to the Government as a head, all working together for the general good, having no personal interests to serve; and, I believe, I am not too sanguine in stating that the ultimate result will be, having water,

the great necessity of life, as free for domestic uses as the air we breathe.

With a practical eye, and feeling that I could not honestly recommend one or other of the foregoing schemes for adoption without a thorough searching investigation of the natural facilities of the country, although in Nos. 2 and 3, namely, "Mr. Darbyshire's propositions," there are many good points, I was therefore, thrown on my own resources, commencing the task with a right good will, a determination to succeed, feeling that each member of the commission with which I have the honor to be associated took an equal interest with myself in its success, fully appreciating my early endeavours to remedy two of the greatest social wants of our hemisphere, namely pure water and an effective drainage, the former now under consideration of the Board, the latter must naturally follow, or rather should be a work of simultaneous execution.

Before going further into the matter, I may state that I purpose dividing it under separate heads.

First, the preliminary selection of a rainfall district, having an ample acreage of catch-water basin, and affording natural facilities for the formation of a reservoir on a gravitating system. Second, a feature survey of the district thus selected. Third, the all-important precursor, before adopting any scheme, viz., an investigation into and careful chemical analysis of the water recommended. Fourth, the preparation of an accurate contoured map and carefully-considered levels, from actual survey, of any locality so chosen.

On the first, second, and third items, it will not be necessary for me to go into any enlarged details, more than touching on the different heads as they occurred in the order of time.

First, the selection of site.

For the greater satisfaction of the members I may here state what has been my governing principle in the selection of a site for a reservoir.

From my earliest connection with the commission, I have advocated the adoption of the gravitation principle, and in all my subsequent and consecutive reports I have invariably urged on their attention the advantages arising from, and the necessity of, providing the supply from a reservoir placed at such an altitude as would give a sufficient command above the level of Geelong proper, and its suburban districts, as would

enable us to have a constant high-pressure supply to all, and on such a scale as would be ample for the rapidly increasing population, and of such a nature as in all future time could be supplemented without loss or deterioration to the then existing works; being, all things considered, the cheapest and best;—the annual cost of the maintenance of such a system being a mere bagatelle as compared to the numerous advantages gained by its adoption.

It being now an admitted axiom with all hydraulic engineers of any standing in the profession in the mother country, (not wedded to antiquated notions,) arising, no doubt, as a general result, from the inquiries instituted by the several European Governments into the subject—that water collected in reservoirs from the rainfall over an extensive catch-water district, is not only purer than river water, but infinitely superior to well water, artesian or others, all of which are liable, more or less, to much mineral impregnation. To such an extent is this now impressed on the minds of the profession and scientific men in general, who may have turned their attention to, or made the subject a study, that the effect has been that nearly all the principal cities of Europe and America—(those in the Mother-country being London, Birmingham, Sheffield, Newcastle-on-Tyne, Halifax, Bristol, Manchester, Liverpool, Edinburgh, Dumfries, Glasgow, Greenock, Dublin, Belfast, Londonderry,)—either are or about to be so supplied, where possible, notwithstanding the princely sums which have been lavished on the old systems, and which are being abandoned and replaced by having recourse to the gatherings from the comparatively pure rainfall and natural surface drainage, where such is practicable, and if possible from the hilly country watershed, being, as a matter of course, purest near the original source, besides giving a command over the lower levels on which the inhabited districts are generally situated.

Taking the foregoing as a truism, and who can doubt it, as regards the old country, how much more is it applicable to this country and to this particular locality, the subject of the present paper, where the rivers are either originally unfit for such uses, or are being rapidly rendered so. The Moorarbool, saline, brackish, nauseous. The Yarrawee, originally one of the purest, least saline, and most wholesome river-waters in the colony, has become totally unfit for domestic purposes,—quite turbid from the uses made of it by the mining population running

as it does through one of the most populous and successful gold mining districts at Ballaarat, it has become so charged with finely comminuted particles of clay, held in suspension, of an unusually persistent character, from the gold-washing and puddling operations, and which I find do not subside even on its reaching the Barwon river, with which it intermixes on its course to the ocean border, and at a distance probably not much short of one hundred miles, taking into account its many tortuous and capricious meanderings through the bush, it is still foul with extraneous matter, next to impossible to arrest, even by the finest filtering media.

Finding the Barwon above its confluence with the Yarrawee apparently pure to the eye, almost transparent, but palpably not so to the palate, being highly charged with saline matter, impregnated, no doubt, by having its course over, or intermixing with, the numerous saliferous springs which there abound.

Whilst on the subject of saliferous springs, I trust it will not be considered out of place, or an unpardonable digression on my part, to make a few remarks thereon, *en passant*, seeing that, as is well known to every settler, they abound in this colony, leaving the toil-worn traveller no alternative but to partake of them, however nauseous the draught, which but turns out to him a Tantalus cup, and instead of the expected pure water, he of necessity has to partake so far of epsom salts and damper for breakfast, or damper and epsom salts for dinner; so *vice versa*.

I doubt not but it may have come under the observation of many, that most of the large as well as smaller salt lagoons are cup-like in formation, which I believe to be caused by a gradual sinking of the outer crust of the earth, as the saliferous springs bring the brine to the surface, and which have found their way thither by "faults in the flag," caused possibly by slight shocks of earthquakes in time past.

To make this theory more readily understood to those who may not have had any experience in mining, more particularly salt mining, I shall further explain what I mean by the "flag." It is a term generally used by the miners in Europe for a very hard earthy matter, of about two feet thick, at some sixty, or it may be a hundred, yards from the surface of the earth, under which the upper strata of rock salt is generally found, varying in thickness from ten to fifteen yards. Brine is made by the passing of water (percolating from a higher level) over this bed, and, becoming saturated with the rock,

escapes to the surface by simple pressure, rising through the faults or fissures which may have been formed as before explained, or other exciting causes. This, when evaporated by our dry atmosphere, in these lagoons, accounts for the crust of salt found in and around them in such quantities.

As the bed of the rock salt is dissolved by the motion of water over it, it becomes brine, and on making its way to the surface, leaving a vacuum, the outer crust will naturally sink, and follow the wasting away of the rock; accordingly we find these lagoons formed, and I doubt not increasing in depth, but so imperceptibly as scarcely to excite a passing notice. It is a well-known fact that such has taken place in the mother country, at Northwich and other salt neighbourhoods, where land formerly elevated is now submerged many feet under water. No doubt this sinking in the old country will, and does take place much more rapidly than with us, which is easily accounted for when I state that it is no unusual thing at many of these places to pump up an average of a thousand million gallons of salt brine per year.

I should mention, that generally, under this first or upper bed of rock salt (that is between the first and second beds), is to be found a stratum, of ten yards or so in thickness, containing no particle of salt, but quite impermeable to water; it is therefore quite natural to expect that the brine from the upper layer will make its way to the surface, just as we find it.

To return:—Being foiled by the impurities of the sources of supply which offered themselves in the neighbourhood of the town, I turned my attention to the source of the Barwon itself, to the elevated districts—the high and densely-timbered ranges, which, as an outlying belt, intercepts and condenses the rain-bearing clouds from abrupt contact with the saturated volume of air, highly charged with humidity from the Southern Ocean, carried landward by the prevailing winds, and, so far as I have been enabled to judge from the geological structure of the country, its general configuration, its wild and precipitous glens, its systems of deeply-indented ravines, abrupt hills, deep creeks, elevated ranges, and extensive gullies, all tend to the belief—in the absence of any well-founded meteorological data, or even statistical information to go on—that the local and visible effects have been produced by the copious outpourings, amounting to torrents of rain, which must have been supplied from the condensing vapours precipitated on its surface; a surface proving the hu-

midity of the climate, clothed with all but perpetual verdure, even in the summer season, when the low lands or plains are literally scorched up, and not a blade of grass to be seen. These circumstances constitute it, as one of best *rain-gathering* districts probably in the colony, the aggregate volume of that falling within our water-shed, I doubt not, will ultimately keep the reservoir where I have decided on, after much and diligent search, in the valley of the Wormbete, well supplied, after making all due allowance for evaporation, leakage, absorption, decomposition, or other waste, in which opinion I am happy to say many of the earliest settlers—Hugh Murray, Esq., Thomas Austin, Esq., R. Bromhead, Esq., Edward Willis, Esq., and Dr. Thompson, &c. &c., who, after some twenty years personal observation,—quite coincide with me.

On the occasion on which I laid before my commission, my report of this district, and a recommendation of the site for the reservoir, I had the honour of their approval, sufficient to warrant me in taking my

Second Step—Namely, a feature survey of the valley and its numerous creeks, dying out, or rather taking their rise south, in the high timbered ranges, abutting against the east and west saddle, separating them from the Retreat Creek of the Wormbete forest, and comprising at least ten thousand imperial acres* of gathering ground within the water-shed marginal line, the surface of which I found to be like the general surface of the colony, hard and impermeable, so much so, that the body of the waters falling on its entire extent quickly drain off, (from its peculiar conformation,) suddenly swelling the numerous creeks and gullies to an enormous size, thus causing rapid but temporary floods after the rain, which, from the formation before alluded to, runs off in four or five days, gorging the Barwon, and causing it to overflow its banks, inundating the surrounding flats, swamps, and lagoons, north of the reservoir, again to find its way into mid-air by evaporation.

Traversing these creeks, and finding that the majority of them, and other minor gullies, were the natural channels of the available rainfall of this favourably circumstanced gathering ground, such as I have attempted to describe and represent by my finished map (which I have the honour to exhibit

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* From a subsequent survey this quantity proves to be fifteen thousand acres.

this evening,) centred themselves by an arterial-like system in the valley of the Wormbete, near Hopkins's pre-emptive purchase, I at once determined on that as the best and most advisable site for the reservoir, provided a more careful inspection, and mature study warranted it. This having brought me to my—

Third step—namely, a chemical examination of the water which I recommended, together with an analysis of fourteen other available waters, more by way of comparison,—to which I need not more than allude, your having a report on these waters by one of the first analytical chemists of the colony, John Macadam, Esq., M.D., who, after patient, long, and laborious manipulation, with myself, in the laboratory of the Commission, has verified, in almost every particular, my original assertions that the sources which I had recommended—namely, the Wormbete and Retreat Creeks,—yielded as pure, if not the purest water in the colony of Victoria, and quite equal to the majority of the purest known waters of the mother country. *Vide* his report, which I have the honour of laying on the table of the Institute.

The completion and success of this analysis brought me to the

Fourth step—the final selection of the site of the reservoir. You will quite agree with me regarding the necessity that exists of bringing considerable practical knowledge, combined with due caution, to bear on the selection of such. The responsibility is not to be under-valued, seeing that the final success of any commission most materially hinges on the site being judiciously chosen, and with such skill as will ensure success.

Subsequent and more mature consideration has but affirmed me in my first resolve, seeing that all that is required in this naturally formed valley of the Wormbete, is the construction of such works as may enable me to arrest and impound the whole of the flood waters of the hilly country, on their onward passage to the sea, by the channel of the Barwon.

Besides, having discovered the possibility of otherwise increasing the quantity very considerably by intercepting the Retreat Creek taking its rise south of the great dividing range of the Wormbete Forest, and running westerly—having its embouchure into the Barwon some miles distant, higher up the stream,) by drifting a short tunnel through the dividing range at a suitable level, into an already formed natural channel, I shall be enabled to convey this additional

supply into the Wormbete reservoir by way of Western Creek (see map). By securing this additional quantity, I would add upwards of ten thousand acres to the already large gathering ground, thus making assurance doubly sure, considering that in our variable climate, it is but prudent to put beyond hazard, or even doubt, the question of supply, by embracing all available sources within compass.

Every attention has also been paid to the principal point in reservoir construction, *i.e.* the natural impermeability of the bottom, and which I have thoroughly ascertained by numerous trial pits, which I ordered the chain and staff bearers to sink to an average depth, whilst my assistants were otherwise employed in camp duties, plotting their field-work.

Care has also been taken in selecting the site for an embankment, within certain limits of deviation,—the foundation of which must either be solid or capable of being made so,)—having good natural abutments on either side of the valley, at the shortest possible span, the height sufficient to impound forty feet of clear water at centre of embankment, exclusive of a subsiding depth of ten feet *additional*, considering, as I do, that the great value of a reservoir, more particularly in these latitudes, depends principally on its *greatest* cubical contents with the *least* possible superficial evaporating surface.

To make this a certainty, and the more palpable to the ready understanding of the commission, and that such may not be altogether depending on the mere assertion of my verbal opinion, I have had an accurate surface survey, longitudinal, and numerous transverse sections, taken at every five chains, across the valley, showing its converging sides, and giving at same time the area of each cross section, and the means of plotting accurate contour lines on the map, describing the tortuous perimeter of the water levels at the three several depths of forty, thirty, and twenty feet at embankment, above the eduction pipe, thereby enabling me to come to as close an approximation as may be of the separate cubical quantities of water retained for use by each proposition. See Table No. III.

TABLE No. III.

Acreable Extent, and Capacity in Gallons, of Wormbete Reservoir.

Contour.	Imperial Acres.	Gallons.
40	252	1,661,318,850
30	184	950,677,092
20	124	583,400,687

The capacity of this reservoir will more readily be understood from the tables which I append to this report, and, viewed in conjunction with the drawings showing water-space within the forty feet contour level, to contain one thousand six hundred and sixty-one millions of gallons.

Within the thirty feet contour level, to contain nearly one thousand millions of gallons.

Within the twenty feet contour level, to contain five hundred and eighty-three millions of gallons.

TABLE No. IV.

Debit and Credit account for two and a half years consumption from Reservoir, at the stinted Melbourne allowance of twenty-five gallons per head per diem for a population of fifty thousand.

	Gallons.
Quantity in Reservoir at the 40 feet contour,	1,661,318,850
Evaporation, &c., as explained (See Table No. VII.)	246,462,969
	1,414,855,881
First year's consumption, at twenty-five gallons per head per diem, ...	456,250,000
	958,605,881
Evaporation as before, on reduced surface, 154 acres.	174,106,880
	784,499,001
Second year's consumption, as before, . .	456,250,000
	328,249,001
Evaporation as before, on still further reduced surface, for six months, ...	100,124,001
	228,125,000
Half-year, or 6 months' consumption as before,	228,125,000

The first, or forty feet contour level, is about half the annual rain-fall, and which would be equivalent to two and a half years' consumption of double the present population, at the Melbourne standard modicum of twenty-five gallons per diem. Even after taking into account the probable maximum waste arising from absorption, decomposition, leakage, and evaporation, on the one hand, and of no rain-fall whatever for the above period on the other.

This, be it remembered, is without taking into account any portion of the evaporation returned to the reservoir during the two and a half years' assumed drought in the shape of dew precipitated on the surface of the quiescent waters of the reservoir, which of itself alone would yield nearly another month's supply, exclusive of the ten feet depth of subsiding space at a lower level, left untouched.

In the absence of all meteorological observations to be depended on, in times past, for this locality, I must per force draw my conclusions from facts founded on those of the nearest adjoining districts where a known careful register of the quantities of rain falling has been kept for a series of years, as indicated by the pluviameter. I grant, however, it is difficult to calculate the rain-fall in any given district, even to an approximation by data resting on observations taken elsewhere; yet, at the same time, in the absence of such valuable and necessary local information, I must say that, in proper hands, the former will approximate nearer the truth than by quoting authorities from another hemisphere, it being exceedingly doubtful, in the present state of meteorological science in the colony, how far it would be safe to rely on such analogy, besides affording no guide in estimating the proportion of rain-fall in so favorably circumstanced a locality as that of Wormbete Forest. Besides, I prefer dealing with facts, when to be had; and, whilst on this subject, I will here record one, not generally known either in the colony or the mother country—a fact regarding the great amount of difference existing between the rain-fall of Melbourne and that of London, and several other cities of Europe. (See Table No. V.)

The synopses of several of the places enumerated are compiled from authentic documents kindly forwarded to me by order of His Excellency Sir William Thomas Dennison, Governor-General of the Australian Colonies; also from W. H. Freeling, Esq., Capt. R.E.; Surveyor-General of South Australia; and the Corporate body of Launceston, Tasmania; A. J. Skene, Esq., District Surveyor of Geelong; to

all of whom I hereby register my thanks for the readiness evinced in forwarding to me the necessary Meteorological returns.

Table No. V.

Climates of Melbourne and London.

Comparative Rain-fall in Corresponding Months.

Australian Months, Victoria.	1847.	1848.	1849.	1850.	1851.	Mean at Melbourne	Mean at London, 20 Years, ending 1846.	European Months, England.
January .	1.28	0.61	0.22	4.17	0.50	.136	2.44	July.
February..	0.97	0.03	1.03	1.37	0.65	.810	2.37	August.
March	2.10	1.61	2.53	0.65	1.43	1.664	2.97	September
April	5.09	1.61	5.45	3.12	1.23	.330	2.46	October.
May	2.07	6.94	3.01	1.43	4.77	3.644	2.58	November.
June	2.76	1.61	0.88	2.76	5.22	2.646	1.65	December.
July	2.63	1.11	4.38	1.98	1.70	.236	1.56	January.
August ..	1.99	4.23	7.62	2.08	3.04	3.792	1.45	February.
September	1.75	2.87	5.01	3.85	4.18	3.532	1.36	March.
October ..	2.33	6.51	1.05	0.28	1.33	.230	1.55	April.
November	2.40	4.17	12.13	3.44	6.91	.581	1.67	May.
December	0.88	2.45	0.94	1.85	0.94	1.412	1.98	June.
Totals in 12 months of each year	26.25	33.75	44.25	26.98	31.90	32.63	24.04	Totals in 12 M'nths of each year

Mean of 5 years. } Excess of Melbourne over London, 8.59 inches. { Mean of 5 years.

Melbourne, 5 yrs.,	1847 to 1851	32·63	London, 20 years, 1846 ..... 24·04
Sydney	do. do.	45·79	Edinburgh, 21 years ..... 25·60
Adelaide	do. do.	24·23	Glasgow, 2 years ..... 33·60
Launceston	do. do.	33·50	Dublin, 6 years ..... 30·87
Bonninyong,	1850 to 1853	29·64	Belfast ..... 36·00
Melbourne	1856	28·60	Great Britain (mean of) .... 32·00
Yan Yean	1856	25·03	Paris ..... 21·00
Geelong, ...	1856	24·72	Rome ..... 36·00

It will be seen in the foregoing Table No. V., that, by placing the rain-fall of London (the Metropolis of the Northern Hemisphere), and that of Melbourne (the Metropolis of the Southern Hemisphere,) in a tabular form, in juxtaposition, an interesting fact is proved to demonstration, viz., that Melbourne exceeds London by upwards of 35 per cent. The table is compiled from the records of the Melbourne Observatory (then kept by William Henry Archer, Esq.,

Assistant Registrar for Victoria), which satisfactorily show that, from a mean of five consecutive years, commencing with 1847 and ending 1851, both inclusive, the Melbourne rain-fall was as high as 32·63 inches, whilst London was but 24·04 inches, taken from a mean of twenty years anterior to 1846, showing a difference of 8·59 inches, or, in other words, an extra one hundred and twenty-five millions of gallons of rain per square mile, leaving a large balance in favor of colonial account, and which but requires the appliances of skill to collect and turn to many profitable uses.

It is a matter of the utmost regret that no earlier complete series of rain-fall data for Victoria (than those I have enumerated) are extant; though several parties, as amateurs, formerly kept registries, yet, from change of residence or other causes daily occurring in a new country, many of them have been so irregularly kept (most dropped into disuse) as to afford but little reliable information.

It will be seen, however, that from such as we have, the authorised registers of the Australian colonies,—that of Victoria, kept at Melbourne,—New South Wales, at Sydney, —South Australia, at Adelaide,—and Tasmania, at Launceston,—all of which I have repeated as an addenda to Table No. V.—give a mean of 34·4 inches per annum, being, as I know, about two and a-half inches in excess of the mean of Great Britain, on the authority of Professor Thomson, a name well known in meteorological science. These registries which I have collated are astounding facts, and from such authorities will rather astonish Europeans who have never been out of the bounds of that hemisphere, and whose preconceived notions lead them to consider we have but little moisture here. I doubt not that this will even startle many of our old colonists, now resident in the mother-country, whose rain experiences whilst in the colony, without scientific registers, led them to imagine we had very much less rain here than in England, whereas quite the reverse is the fact.

It is not out of place here to reply to a query which may have, or at all events will, occur to your minds. Has the author of this paper kept any register at Wormbete? I answer in the affirmative. Considering it to be a prudent step in the eyes of my Commission to strengthen the opinions already enunciated by me in regard of this locality, I at once had a rain-gauge manufactured on the best principle, placed under the care of a gentleman of known honor and integrity, John R. Hopkins, Esq., and who, equally with

myself, felt an interest in daily recording its readings, and which his constant residence there, and regular habits, enabled him to do.

Considering that the members of the Institute would feel but little interest in the returns of but a few months, since the guage was fixed at Wormbete, I have not included it in the above table; but it may be satisfactory to know that up to the latest date it records a rain-fall exceeding Geelong by *forty-five* per cent., quite equalling Melbourne; and exceeds Yan Yean by *thirty* per cent.*

Taking the records of Melbourne, as before stated, on Mr. Archer's authority, as showing a rain-fall of 32·63, and that of the Yan Yean (twenty miles north of Melbourne) on the authority of Charles James Griffith. Esq., M.L.A., the President of the Sewerage and Water Commission, who states it as being as high as 36 inches per annum, and which I believe, from my own experience, to be very considerably under the mark.

These, with simultaneous observations upon the quantity discharged by the outlets of this (Yan Yean) now ascertained area of surface drainage, and a comparison of the quantity of rainfall, will afford something like data of the greatest importance. This, together with a careful study of the configuration of the surface of that district, with its attendant or exciting causes, enable me to approximate pretty near the truth of what proportion of rain can be considered available; no doubt, however, this must be modified by the local circum-

* Subsequently I have been enabled to fill up a Six Months' comparative Table, as annexed, of the before mentioned localities, quite verifying my anticipations:—

Comparative Rain-fall at Wormbete, Geelong, Melbourne, and Yan Yean.

MONTHS. 1857.	*Wormbete.* J. R. Hopkins, Esq., Observer.	*Geelong.* A. J. Skene, Esq., Observer.	*Melbourne.* R. B. Smyth, Esq., Observer.	*Yan Yean.* Chas. Taylor, Esq., Observer.	MONTHS. 1857.
January	0·82	0·70	1·23	0·97	January.
February ...	2·35	3·39	3·98	1·33	February.
March.....	2·84	1·99	3·80	3·61	March.
April	1·70	1·07	0·99	0·78	April.
May.....	2·77	1·72	2·00	2·05	May.
June	3·24	1·58	1·99	1·89	June.
	13·72	9·45	13·99	10·63	

stances of the Wormbete district, meteorological, hydrographical, and physical; evaporation, rain-fall, general configuration, soil, &c. &c., not only within the bounds of the catch-water district, but the surrounding country generally, as well as other varied circumstances, such as the prevailing winds, and other counter-agents bearing on the results. All must be taken into account and properly considered, with such accurate information as I may have been enabled to collect and record, so as ultimately to give me a perfect basis from which to deduce a calculation that can be depended upon in its resultant facts, not forgetting to take into account that the water shed commences at a high level, (something like twelve to fifteen hundred feet above the sea board,) falling with steep but regular gradients towards the valley, ensuring a rapid conduction of the water falling on its surface to the reservoir, thereby diminishing the likelihood of extensive evaporation and mineral impregnation.

Touching the *vexed question* of evaporation in these colonies, I may here state that the hitherto theoretical opinions formerly held by several parties in Victoria, have been considerably toned down by practical experience. It should not, however, be forgotten, that evaporation is more or less modified by several attendant causes acting on the atmosphere, such as temperature, moisture, force and direction of the wind, all tending to that uncertain condition, which, ever varying the evaporation, precludes the possibility of having any fixed rule, excepting an average founded on actual observation in the locality, and extending over a considerable space of time.

My opinion, founded on actual colonial observation, on large bodies of deep and almost quiescent water, such as reservoirs in a still state, enables me confidently to pronounce it as considerably under fifty-two inches per annum, and very probably the opinion held by Major (now Colonel) Cotton, from more extended observations in the colony as regards time, are still more in conformity with the fact. His opinion was forty-five inches.*

* Touching evaporation I have considerable pleasure in adding that, from subsequent information from the resident engineer at Yan Yean, he states that from careful observation during the time that the aqueduct, feeding the reservoir was closed for the completion of the tunnel, the water being then five and a-half feet deep in reservoir, the evaporation from the same was one-tenth of an inch per day during the *summer months* of January, February, and March, 1856. And again, in October of the same year, during which month the supply had been taken from the river, the evaporation was much the same, being an average for the entire year of but 36 inches.

As a general principle, I have advised that the consumption for Geelong be apportioned as follows, (looking on the standard modicum—"twenty-five gallons"—allowed in Melbourne, as no criterion for colonial guidance,) having the likelihood of a most abundant and unlimited supply. In my calculation I allow sixty gallons per head, per diem for the summer consumption, to supply the ordinary domestic wants, &c. &c., as hereafter enumerated, for a population numbering fifty thousand souls.

For the winter half-year, when consumption necessarily (for public purposes) is very much diminished, I allow forty gallons, being a mean of fifty gallons per head per diem, as the basis on which I found my calculations for the entire yearly consumption, and distributed under the following heads:—

1st. Domestic Uses.
2nd. Hospitals, Dispensaries, &c.
3rd. Asylums.
4th. Schools.
5th. Gaols, Court-Houses, &c.
6th. Public Wash-Houses and Baths.
7th. Shipping.
8th. Horse and Cattle Troughs.
9th. Extinction of Fires.
10th. Cleansing and Watering Streets.
11th. Flushing Sewers, Drains, &c.
12th. Ornamental Fountains.
13th. Public or Botanical Gardens.
14th. Gardening Purposes.
15th. Railways.
16th. Steam Engines.
17th. Manufactories.
18th. Abattoirs,

And Public Buildings in general, &c. &c.

In calculating the supply, I take the water-shed, being a surface catch-water basin, assumed to be, at a most moderate estimate, *ten thousand* acres in extent, within the marginal apex, the drainage of which flows into the Barwon, by way of Wormbete Valley, where I purpose impounding it by the formation of an embankment fifty-eight feet in height.

Table No. VI.

SUPPLY.

Assumed Rainfall.

	inches.
See data, Table No. VIII. taken at	36·00
Dew	0·00
	36·00
Evaporation	27·00
25 per cent. available rain-fall	9·00

	Gallons.
6,666 imperial acres, or two-thirds of watershed, allowing 9 inches or 25 per cent. as available rainfall	1,356,758,310
3,334 imperial acres, or two-thirds of watershed in the immediate vicinity of the Reservoir, or 50 per cent. as available rain fall	1,357,165,378
10,000	
252 imperial acres surface level of reservoir, at 40 ft. contour—	
Rainfall .. .. 36·00 inches.	
Dew .. .. 4·00 = 40·00	227,958,192
Available gallons of water per annum	2,941,881,880

Table No. VII.

Cubical Capacity of Reservoir, in Gallons.

	Cubic Feet.	Gallons.
Wormbete Valley proper ..	207,976,236	
Western Inlet	53,541,047	
North-east Inlet	5,147,058	
	266,664,342, or	1,661,318,850
Evaporation.		
Acreage at forty feet level of surface 252	Mean 218 acres at	
Ditto thirty feet 184	4·166 feet	246,462,969
		1,414,855,881
Demand.		
Consumption of 50,000 population, at an average of fifty gallons per head per diem, for all purposes, for twelve months		912,500,000
Showing a balance of above five hundred millions of gallons, as provision against occasional droughts		502,355,881
Consumption for an additional six months ..		456,250,000
Balance of forty-six million gallons for evaporation and contingencies, after supply for eighteen months		46,105,880

The working out of the last table (No. VII.) shows a balance of water still on hand from the *once filling* of the reservoir, and after supplying a 50,000 population for eighteen months, and without receiving during that period any additions to its quantity.

It will be observed that the quantity would suffice for the present population of 25,000 for two and a half years; or, by reducing the allowance per head to the *Melbourne standard* of twenty-five gallons, for five years.

This, let it be understood, is without infringing on but half the rain-fall, the whole of which being (2,941,881,880) two thousand nine hundred and forty-two MILLIONS of gallons—see Table No. VI. Were it impounded, it will readily be understood that there would be a sufficiency (after deducting for yearly evaporation) for nearly double the above periods; say *three, five,* and *eight* years respectively, quite sufficient to lull all anxieties respecting the probability of a water famine, even if three or four consecutive years of drought should ever unhappily again occur, as it has in the memory of many of the early settlers. It leaves a very ample margin to meet contingencies of any nature or kind, and more particularly all cavil.

It may be, that superficial observers, or persons who have not made hydraulic questions their study, may at first sight imagine that I have either set down the available rain-fall at a high figure, or from imaginary data.

In contravention of such idea, I append Table No. VIII. of actual rain-fall at Yan Yean reservoir, and quantities ascertained both by careful gaugings at mouth of inlet tunnel, and checked by water-gauge staff, permanently fixed at the outlet tower of the reservoir. I wish to show the several facts deducible therefrom.

Table No. VIII.

Time, 1856.	Rain Gauge.	Quantities calculated at a per centage on Rain-fall of Water Shed.	Gallons.	Gallons.	Millions Gallons.
June	1·70	40,000 acres drained by Plenty River, 33 per cent. ..	507,478,356		Quantities as gauged at Inlet, and checked by Tower Staff.
		5,500 acres, drained by Reservoir 65 per cent. ..	137,442,054		
		1,300 acres, surface of Reservoir, 100 per cent. ..	49,978,929		
				694,899,339	698
		40,000 acres, as above, 35 per cent.	712,369,630		
July	2·25	5,500 acres, as above, 70 per cent.	195,901,571		
		1,300 acres, as above, 100 per cent.	66,148,582		
				974,419,783	974
	3·95			1,669,319,122	1,672

Table No. IX.

Synopsis, showing Register of Pluviameter in Victoria for same months.

Yan Yean. 600 feet above sea level.	Melbourne. 130 feet above mean sea level.		Geelong. 125 feet above mean sea level.
June and July, 1856.	Time. Mean of Five Years, June and July ending 1851.	Time. June and July, 1856.	June and July, 1856.
3·95	5·006	5·135	4·46

The above tables, Nos. VIII. and IX., are compiled from accurate and authentic data, (kindly supplied me by Mr. Charles Taylor, resident engineer at Yan Yean reservoir, to whom I tender my thanks,) and checked from means within my own control. The quantities of water, 35, 70, and 100 per cent. respectively, may seem to be excessive for the registered rain-fall, but I know that nearly as much water escaped by the bye-wash, *i.e*, the River Plenty; that is, off the 40,000 acres, (the 5500 acres being the original and only water-shed of the reservoir swamp, to which it finds its way irrespective of the artificial aqueduct.) This

reservoir having no bye-wash proper, therefore, strictly speaking, the word "bye-wash" is a misnomer, as at present applied by the authorities in connection with the scheme; it is simply an outlet overflow, constructed at the termination of the embankment. The real bye-wash is the original River Plenty, by which all that the aqueduct cannot receive pursues its onward course to the sea.

These tables prove one of two things—either that the pluviameter indicated less than the real fall, or that nearly all, if not quite all, the rain-fall on the 40,000 acres, found its way towards the reservoir, and would have nearly filled it, if the two-mile aqueduct had been *capacious* enough to convey it.

That the whole quantity came down I do not for a moment doubt; and it arose from the fact of the ground having been thoroughly well saturated prior to the rain now registered for June and July, 1856, thereby proving that heretofore the theoretical allowance of colonial engineers and others for available water is much *under the mark.*

I would have it, therefore, inferred, that the per centage as allowed by me for Wormbete is no way in excess, but otherwise scanty, seeing that it is a much more favorably circumstanced gathering-ground, all things considered, than the Plenty.

Table No. X.

Showing the proportion of Evaporating Surface of various Home and Colonial Reservoirs and natural Lakes, as compared to their acreable Water-shed in extent:—

Lake Corangamite	One-ninth.
Lake Colac	One-tenth.
Lake Wardyallock	One-eleventh.
Rivington Pike (England)	One-twentieth.
Yan Yean	One-thirtieth.
Wormbete	*One-sixtieth.*

In regard to the purity of the Wormbete reservoir waters, it should be borne in mind that from the time on which they are condensed on the surface until they are impounded in the reservoir there are no lagoons to fill, no sedgy marsh lands, no extensive swamps to pass over, absorbing much, discolouring the residue, and creating vegetable poison; no fallow lands or agricultural district to impregnate more or less by the impurities which they contain, and which may be gathered up by the waters passing over them; no contami-

nating influences arising from sheep or wool-washing establishments; and, being far removed from population, there are few floating impurities in the air, and no sewage matter to deteriorate the surrounding soil; scarcely a human being, all being still, save the occasional ringing note of the solitary woodman's axe; and it should not be forgotten that animal matter taken hold of in any shape by the solvent power of pure water, though in minute particles, is held by the first authorities to be prejudicial in regard to health.

It should further be borne in mind (and it is no slight recommendation,) that from the very natural configuration of the thousands of acres in this forest, it never can, in all time, become an agricultural district—must remain as it is, save being denuded of its timber, thereby giving an assurance that coming generations will, equally with the present, enjoy a pure water-gathering ground and pure water, without the intervention of artificial filters, many of which, in some of the finest works in the mother country, are exceedingly troublesome, and liable to get out of order.

The Retreat yields water of the greatest natural purity, the pellucid stream of which is comparatively free from even vegetable contamination, (notwithstanding the adjacency in such numbers of the tall but graceful and luxuriant tree-fern, and other plants of an almost tropical growth;) little or no perceptible change has been imparted to the water thereby; it is deliciously cool, strongly reminding me of the bright sparkling waters of the mother country; it is almost as pure as the purest known, and very much better adapted for domestic uses than most, being less impregnated either with mineral or chemical constituents—(*vide* Dr. Macadam's Report)—not requiring filtration, pure, brilliant, and entirely unexceptionable in colour or taste, betraying no organic taint, and evincing *prima facie* great purity.

Having shown that more than a sufficiency of water is procurable, it now rests with my Commission to order the necessary steps next in progression to be taken, by which so abundant a supply can be made available for the town, by the construction of such works as may be required for collecting, conveying, and distributing that which nature has put within our grasp, namely, the fundamental groundwork for creating a never-ceasing gravitation supply.

Having given much and serious study to the ichnographical features of the town and its suburban districts, with a view to high and constant service, it but remains for me to

say, that, seeing it is a matter of the greatest importance, and should be kept most prominently in view, the supply being not only ample, but good and unlimited, with an ever-continued pressure constantly on, available at all times day or night from an altitude sufficient to command the upper story of the highest house in the most elevated district, sufficient to quickly and efficaciously extinguish fires, however extensive, and that without incurring any additional outlay for power, save the fire-plugs or hydrants, protecting the town against the devastating element of fire, a striking proof of the lamentable effects of which we so lately have had in the ravages committed in the Market Square, Geelong, on the night of 26th December last, destroying in so short a space of time £50,000 worth of property, which, had these projected works been but complete and in a working state, they would most assuredly have kept the total loss under £500, a difference of £45,500,—a large amount consumed by this one fire alone, which would have formed a considerable item in the expenditure necessary for the formation of water works.

Thus,—I take it, the future protection of the citizens and their properties will be secured from such a scourge by simple pressure, obtained from such an altitude as will render obsolete the primitive mode now obliged to be resorted to, as a matter of necessity, by an otherwise well-regulated, energetic, and fearless fire brigade, bringing to their aid a comparatively weak and inefficient mechanical power.

Suffice it to say that by this gravitation we avoid the necessity for the erection of steam-engines, or other expensive machinery, in duplicate or otherwise, ever liable to get out of order. We also avoid elevation syphons, with all their paraphernalia, which is rendered unnecessary, besides other expensive appendages too numerous to detail within the limited compass of this paper, nor is it desirable that I should do so, seeing that any or every pumping scheme is superseded by the adaptation of nature's own providing—a GRAVITATION SCHEME, *eligible, safe, simple,* and *comprehensive.*

It may be that I shall have the honour on a future occasion to submit, (subject to your wishes,) a further or supplemental paper, on an extended scheme, the possible formation of a reservoir, in the same locality, covering an area of four hundred acres, depth of water seventy feet at embankments, and the cubical contents of six hundred and forty-five million feet, or four thousand and eighteen million gallons in quantity;

the which is worthy of our consideration in a climate such as this, where the rain-fall has been known to be casual, exceedingly precarious, uncertain, and occasionally scanty in amount; sufficient to meet the views of the most utopian opinions on increasing population in any country, and more particularly that of our adopted one.

In the experience of the older colonists we have had two and even three (some say four), consecutive years of drought; if such should unhappily again occur, it may be that the population of Melbourne might be dependent on Geelong for water. Such being the case, by the erection of an embankment of the magnitude contemplated in my supplemental paper, we would have enough and to spare, so that Melbourne could be assisted without infringing on the rights of Geelong.

Foreseeing the possibility of deriving a revenue more than enough to warrant an extra expenditure of considerable capital by a well-digested system of *reproductive works*, using the surplus waters capable of being impounded—

1st. For use of Man.
2nd. Use of Animals.
3rd. Sheep Washing.
4th. Irrigation.
5th. Irrigation as Manure.
6th. Motive Power, by the use of hydro-pneumatic engines, or others.

I believe I am warranted in stating that the value of water for irrigation purposes is by no means as yet sufficiently known in the colony, but it is to be hoped that the day is not far distant that its merits will be appreciated as it deserves. And in connection with this, I will but draw your attention to a few facts connected with such a use in a climate not unlike ours, namely, the innumerable tanks and reservoirs of our conquered provinces of India, which had been constructed under the native princes for the use of their people. Scarce a village is without one, and where the population was dense, requiring greater, such as the present Madras Presidency, they had a reservoir thirty miles in circumference, having an embankment of some twelve miles long, and approaching a depth of fifty feet.

In reference to this subject I doubt not but when the time arrives for our Government to take the matter up in detail,